

Flood Hazard Evaluation

Moose River

Concord, Vermont

February 1991

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1.0 INTRODUCTION

1.1 Purpose of the Study

The report provides information about the severity of flooding from the Moose River in the Town of Concord, Vermont. This information is intended for use by state, local and regional planners in land use and floodplain management.

1.2 Authority

Authority for U.S. Army Corps of Engineers participation in this effort is sanctioned by Section 206 of the 1960 Flood Control Act, (Public Law 86-645), which states:

"...The Secretary of the Army, through the Chief of Engineers, Department of the Army, is hereby authorized to compile and disseminate information on floods and flood damages, including identification of areas subject to inundation by floods of various magnitudes and frequencies, and general criteria for guidance in the use of floodplain areas and to provide engineering advice to local interests for their use in planning to ameliorate the flood hazard..."

1.3 Acknowledgments

The study was conducted by the New England Division, Army Corps of Engineers, under the general supervision of Mr. Joseph L. Ignazio, Chief, Planning Directorate, Mr. Paul Pronovost, Chief, Basin Management Division, and Mr. John Kennelly, Chief, Long Range Planning Branch. The Project Manager was Mr. Bill Mullen who also prepared the HEC-2 computer analysis and delineated the floodplain boundaries; Mr. Mark Geib performed the hydrology. Corps of Engineers employees surveyed the cross-sections. Mr. Roy Gaffney of the Department of Environmental Conservation, Agency of Natural Resources, State of Vermont, surveyed the elevation reference marks used by the Corps surveyors.

2.0 AREA STUDIED

2.1 Scope of Study

The area studied (see Figure 1) includes 7.5 river miles of the Moose River in the town of Concord, Vermont. The downstream study limit is the Kirby-Concord corporate limit; the upstream limit is the Victory Road bridge crossing of the river in Concord.

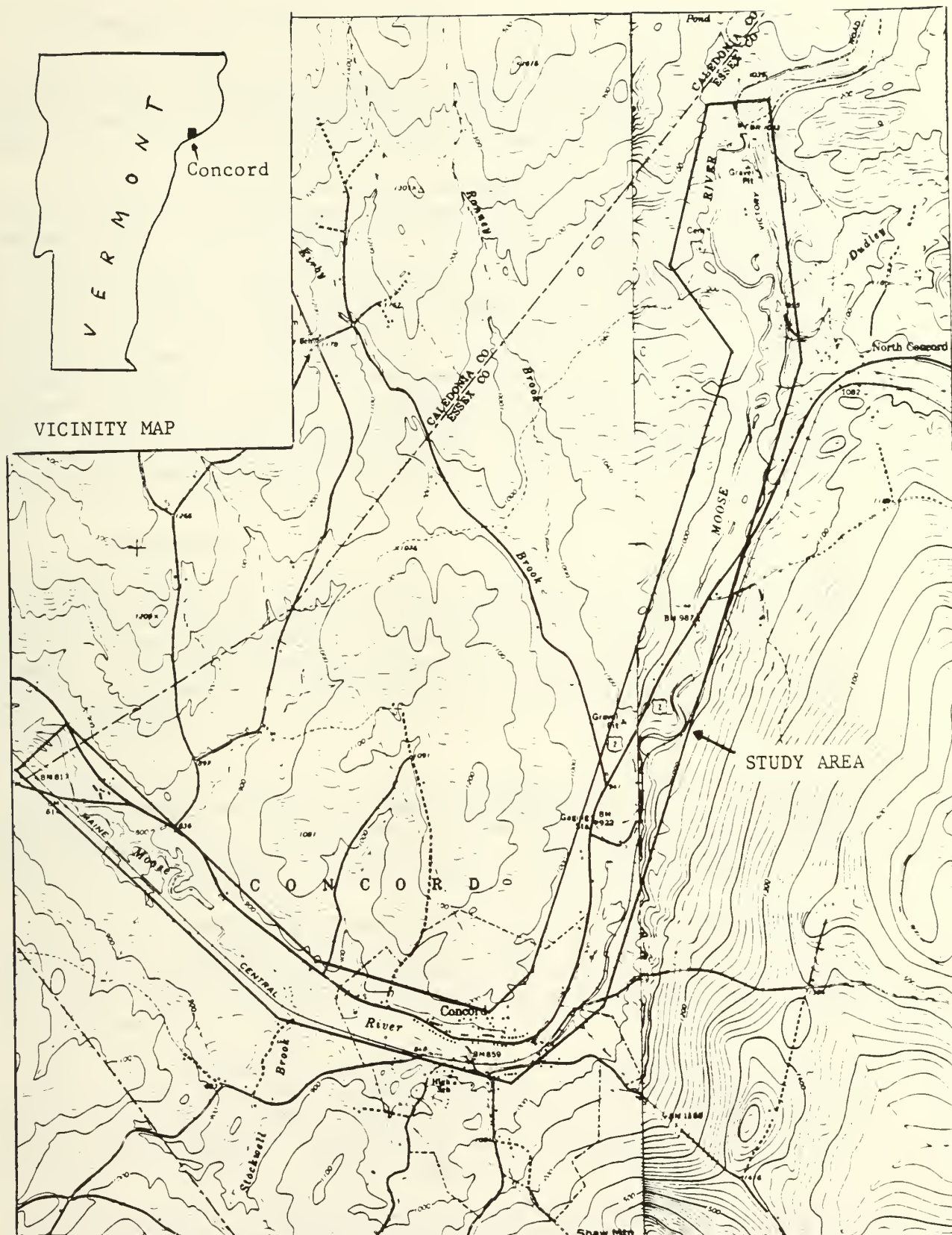


FIGURE 1 - STUDY AREA
MOOSE RIVER
CONCORD, VERMONT

2.2 Community and Basin Description

The Town of Concord, Vermont is located in Essex County on the New Hampshire border in northern Vermont. It has no industrial or farming economic base, but instead serves primarily as a bedroom community to nearby communities. Population of the 52 square mile town is about 1200.

The Moose River originates in the mountains north of Gallup Mills, flows southerly to Concord, and then westerly to its junction with the Passumpsic River at St. Johnsbury. The river gradient is very steep in the headwaters and practically all of the small headwater brooks develop on mountain slopes. The outstanding feature of the Moose River watershed is the very large flat swampy area containing well over 1,000 acres located in the approximate center of the watershed north of the settlement of Victory, Vermont. The upper Moose River, less than 11 miles in length, together with several small streams less than 5 miles long, enter the perimeter of this swamp in a fan-shaped pattern producing a relatively quick concentration time for the natural inflow to this area. The elevation of the headwater mountain peaks is over 3,000 feet. In general, the drainage area's terrain has moderate slopes and is heavily wooded.

2.3 Flood History

Floods on the Moose River may result from early spring storms combined with melting snow, such as the flood of March 1936, or from summer or fall storms in which floods result from rainfall alone, such as the flood of November 1927. Streamflows of the upper Moose River have only been recorded since 1947. The greatest discharge recorded at Victory, Vermont was 4,340 cfs on July 1, 1973. The various floods and their causes are discussed below:

November 1927. The storm of 3 to 4 November was one of the most intense ever recorded in the northern New England region and resulted in widespread flooding. The storm centered over the state of Vermont with an estimated average rainfall of about 6 inches within the Passumpsic River basin. At St. Johnsbury, 6.6 inches fell in the two-day period.

March 1936. Peak flood flows on the Moose River on 18 March at Victory and St. Johnsbury were 2,850 cfs (est.) and 4,780 cfs, respectively, resulting from precipitation and melting snow. Total inches of rain and water equivalent of snow cover which melted from 9 to 21 March was approximately 13 inches.

May 1972. Unseasonably warm temperatures accompanied by a 3-day rainfall on high antecedent moisture conditions in the watershed caused flooding of the Moose River. Total rainfall from 2 to 4 May was 2.8 inches at St. Johnsbury. The peak flow of the Moose River for this event was 5,820 cfs recorded at the USGS gage at St. Johnsbury on May 5.

June/July 1973. During the last four days in June, a strong, moist tropical airflow in association with a stationary frontal system resulted in moderate to heavy shower activity over much of New England. Rainfall amounts varied from 8 to 10 inches in the high mountains of New Hampshire

and Vermont. The heavy precipitation associated with this event caused major flooding in the watersheds of Vermont and New Hampshire that drain the Green and White Mountains. In the Passumpsic watershed, flood discharges equalled or approached the devastating floods of November 1927 and March 1936. The peak flow on the Moose River at Victory was 4,340 cfs, and 5,620 cfs at St. Johnsbury on July 1, 1973.

March/April 1987. During approximately a one-week period beginning at the end of March 1987, a pair of intense rainstorms hit most of New England. These two storms, augmented by snowmelt in the mountains and northern areas resulted in widespread flooding. Rainfall amounts of 2 to 3 inches fell on snowpacks having 3 to 5 inches of water equivalent in northern New Hampshire and Vermont from 31 March to 8 April. A peak flood flow of 4,180 cfs was recorded on the Moose River at Victory on 31 March.

3.0 ENGINEERING METHODS

Standard hydrologic and hydraulic study methods were used to determine the flood data presented in this study. Flood events of a magnitude which are expected to be equalled or exceeded once on the average during any 10, 50, 100, or 500 year period (recurrence intervals) have been selected as having special significance for flood plain management. These events, commonly termed the 10, 50, 100 and the 500 year floods have a 10, 2, 1 and 0.2 percent chance, respectively, of being equalled or exceeded during any year. Although the recurrence interval represents the long term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The analyses reported here reflect flooding potentials based on conditions existing at the time of completion of this study.

3.1 Hydrologic Analysis

Hydrologic analysis of 42 years of data (1947 to 1988) recorded at the USGS gage in Victory, Vermont was performed to establish peak 10, 50, 100 and 500 year discharges for the Moose River. The peak discharge frequencies were developed by statistical analysis of the recorded flow data in accordance with procedures set forth in Bulletin 17B, "Guidelines for Determining Flood Flow Frequency" by the Interagency Advisory Committee on Water Data, U.S. Geological Survey, U.S. Department of the Interior. A regional skew was adopted in the analysis. Estimated peak discharges at Concord, Vermont were determined by application of a transfer method to the discharges determined at Victory, Vermont. A transfer factor equal to a drainage area ratio to the 0.8 exponential power was adopted to the Victory USGS gage record analysis.

Hydrologic analysis of 55 years of data (1928 to 1983) recorded at the USGS gage (discontinued) at St. Johnsbury was also performed for purposes of comparison. The flows estimated for Concord using the procedure described above appear reasonable when compared to the flows published in the Flood Insurance Study for the Town of St. Johnsbury (Ref. 2) for the Moose River at its confluence with the Passumpsic River.

Table 1 summarizes the drainage area peak discharge relationships for the Moose River at various locations.

TABLE 1 - SUMMARY OF DISCHARGES AT VARIOUS LOCATIONS
ALONG THE MOOSE RIVER

<u>Location</u>	<u>Drainage Area</u> (sq. miles)	<u>10-Year</u> (cfs)	<u>50-Year</u> (cfs)	<u>100-Year</u> (cfs)	<u>500-Year</u> (cfs)
Victory USGS gage	75	3,140	4,240	4,730	5,970
Concord, Vt	90+	3,625	4,895	5,460	6,895
St. Johnsbury at gage	128+	4,620	6,700	7,690	10,300
St. Johnsbury at mouth	128	4,720	6,970	7,770	10,250

3.2 Hydraulic Analysis

Hydraulic characteristics were analyzed to determine the water surface elevations of the Moose River for the selected 10, 50, 100 and 500 year recurrence intervals. Field surveys were conducted in order to obtain the cross-section shapes, the structural geometry of the bridges, and the Manning's "n" roughness coefficients. The roughness coefficients for the Moose River ranged from 0.035 to 0.045 for the channel and from 0.040 to 0.085 for the overbank areas.

The U.S. Army Corps of Engineers HEC-2 water surface profiles computer program, (Ref. 7), was used to develop the water surface elevations of floods for the selected recurrence intervals. Table 2 lists water surface elevations at various frequencies of occurrence for each cross section surveyed and Plates 1 to 4 show flood profiles of computed water-surface elevations for the selected floods. Exhibit 1 describes the locations and elevations of the reference marks used in surveying the cross-sections. All elevations cited in this report are referenced to the National Geodetic Vertical Datum (NGVD) of 1929.

The HEC-2 model was started over a mile downstream at the St. Johnsbury-Kirby corporate limit. Starting water surface elevations for the various frequencies of occurrence were taken from the St. Johnsbury Flood Insurance Study (Ref. 2) for free flow (non-ice) conditions at the St. Johnsbury-Kirby corporate limit, although the regulatory base flood elevation at the corporate limit (in the St. Johnsbury study) was based on ice jam effects. Although ice jams or debris blockage could potentially raise flood elevations above those calculated in this report, the hydraulic analysis for Concord is based only on unobstructed flow. Ice jams are not a problem in Concord according to the Vermont Department of Environmental Conservation; nor were any historic ice jams noted in Concord in a Corps study of ice jam problems in Vermont and other New England states (Ref. 10).

The cross-sections used in the HEC-2 analysis were widely spaced due to study constraints and the desire to examine the entire reach downstream from the Victory Road crossing of the Moose River. The wide spacing was not believed to present a significant problem.

TABLE 2 - CALCULATED WATER SURFACE ELEVATIONS FOR
THE MOOSE RIVER IN CONCORD, VERMONT

<u>X-sec no.*</u>	<u>Recurrence Interval</u>			
	<u>10 Year</u> (ft, NGVD)	<u>50 Year</u> (ft,NGVD)	<u>100 Year</u> (ft,NGVD)	<u>500 Year</u> (ft,NGVD)
3	805.3	806.6	807.1	808.2
4	806.0	807.3	807.7	808.8
5	807.4	808.5	808.9	809.9
6	807.8	808.9	809.3	810.2
7	813.1	813.7	813.8	814.2
8	833.3	833.5	833.7	834.0
9.1 d/s bridge	852.8	853.7	854.0	854.9
9.2 u/s bridge	853.0	854.0	854.4	855.4
10	860.2	861.2	861.5	862.2
11.1 d/s bridge	868.8	869.9	870.3	870.9
11.2 u/s bridge	869.1	870.3	870.7	871.3
12	889.2	889.6	889.8	890.1
13.1 d/s bridge	916.6	917.0	917.3	917.9
13.2 u/s bridge	918.3	919.5	919.9	920.7
14	944.7	945.8	946.3	947.4
15 at Rte. 2	967.8	969.1	969.7	971.0
16	973.1	974.4	974.9	960.1
17	974.0	975.4	976.0	977.1
18	975.4	977.0	977.5	978.7
19	978.5	979.4	979.7	980.6
20.1 d/s bridge	1004.6	1005.0	1005.3	1005.9
20.2 u/s bridge	1005.3	1006.4	1007.0	1008.4

* Cross-sections 1 and 2 are located downstream from Concord.

4.0 FLOOD PLAIN MANAGEMENT

4.1 Flood Boundaries

The 100 year flood is usually the base flood for purposes of floodplain regulation. The 500 year flood is used to indicate additional areas of flood risk. Plates 5 and 6 show the 100 and 500 year floodplain delineations using elevations determined at each cross section. Between cross sections, the flood boundaries were interpolated using 20-foot contour USGS topographic maps of the area (Refs. 3 and 4). The floodplain boundaries have been superimposed on the State of Vermont's official base maps (Ref. 9). If the 100 and 500 year flood boundaries are either close together or co-linear, the sheets show only the 100 year boundary. Small areas, such as islands may lie above the flood elevations. These areas are not subject to flooding but, because of map scale limitations, they are not shown as out of the floodplain. If there is a question regarding the exact water surface elevation calculated at any location, the flood profiles on Plates 1 to 4 should be consulted because of their greater accuracy.

4.2 Floodways

Encroachment on the floodplain, such as artificial fill, reduces the flood carrying capacity of rivers, increases the flood heights of streams, and increases flood hazards in areas beyond the encroachment itself. One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard. The concept of a floodway is used as a tool to assist local communities in this aspect of flood management. Under this concept, the area of the 100-year flood is divided into a floodway and a floodway fringe. The floodway is the channel of a stream, plus any adjacent flood plain areas that must be kept free of encroachment in order that the 100 year flood may be carried without substantial increase in flood heights. Minimum standards limit such increases in flood heights to 1.0 foot, provided that hazardous velocities are not produced. Floodway boundaries are shown on Plates 5 and 6. Table 3 lists pertinent data for the floodway.

TABLE 3 - FLOODWAY DATA
MOOSE RIVER, CONCORD, VT.

<u>Cross- Section*</u>	<u>Floodway</u>		<u>Mean Velocity (ft/sec)</u>	<u>Water surface elevation</u>		<u>Difference (ft)</u>
	<u>Width (ft)</u>	<u>Section Area (sq ft)</u>		<u>With Floodway (ft,NGVD)</u>	<u>Without Floodway (ft,NGVD)</u>	
3	126	1231	4.4	807.5	807.1	0.4
4	162	1095	5.0	808.1	807.7	0.4
5	467	3021	1.8	809.6	808.9	0.7
6	349	2565	2.1	810.1	809.3	0.8
7	288	708	7.7	814.2	813.8	0.4
8	294	873	6.3	834.5	833.7	0.8
9.1	89	625	8.7	854.5	854.0	0.5
9.2	89	673	8.1	855.0	854.4	0.6
10	166	607	9.0	861.5	861.5	0.0
11.1	54	537	10.2	871.2	870.2	1.0
11.2	54	563	9.7	871.7	870.7	1.0
12	148	527	10.4	890.7	889.8	0.9
13.1	104	694	7.9	918.3	917.3	1.0
13.2	166	1129	4.8	919.8	919.9	0.0
14	75	411	13.3	946.3	946.3	0.0
15	116	925	5.9	970.2	969.6	0.6
16	97	1037	5.3	974.9	974.9	0.0
17	82	956	5.7	976.0	976.0	0.0
18	135	1236	4.4	977.7	977.5	0.2
19	349	1576	3.5	980.5	979.7	0.8
20.1	68	422	12.9	1005.3	1005.3	0.0
20.2	68	538	10.1	1007.0	1007.0	0.0

* Cross-sections 1 and 2 are not located downstream from Concord.

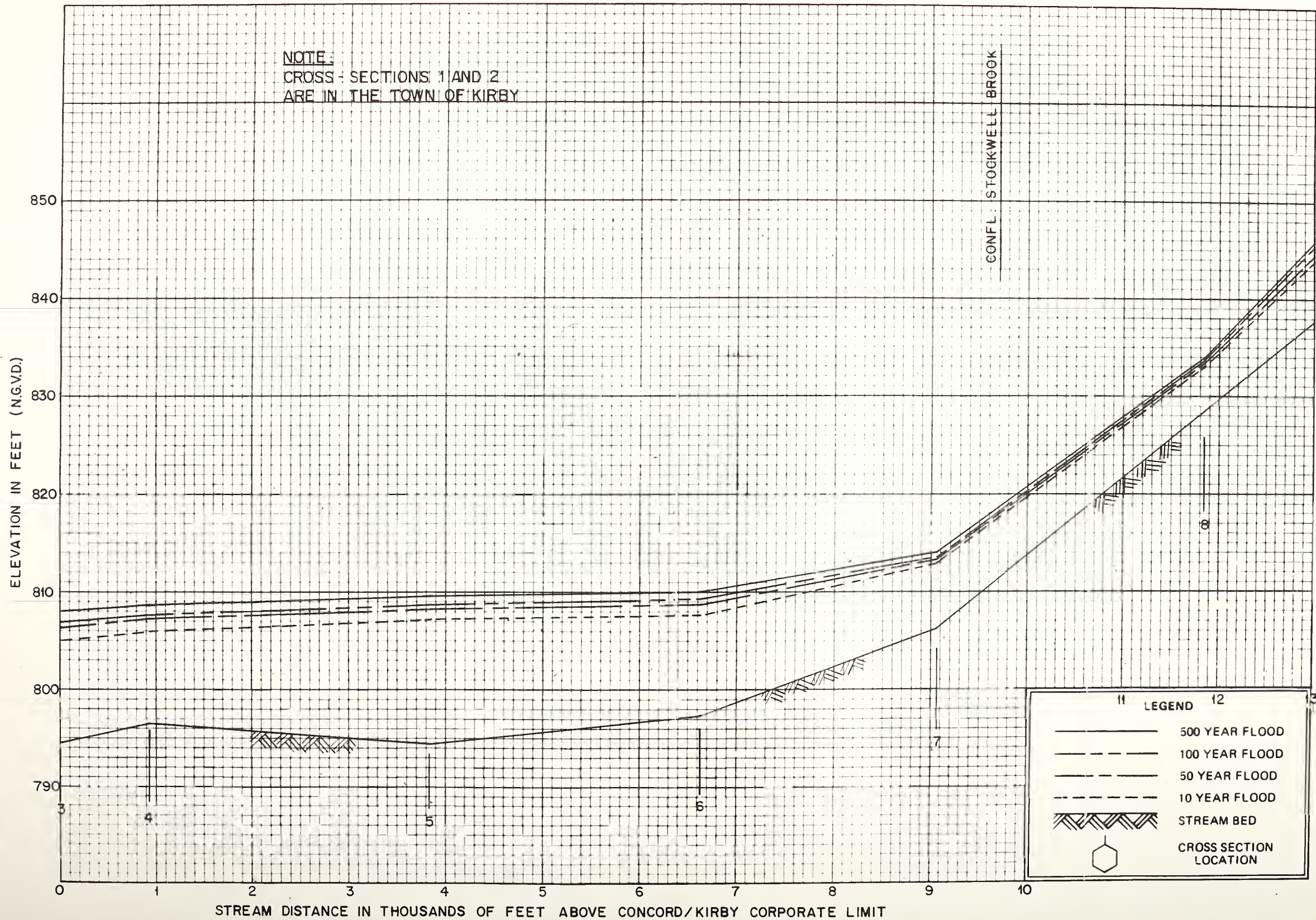
5.0 BIBLIOGRAPHY

1. State of Vermont, Department of Water Resources and Environmental Conservation, Field Survey of Reference Marks in Concord, 1990.
2. U.S. Department of Housing and Urban Development, Federal Emergency Management Agency, Flood Insurance Study, Town of St. Johnsbury, Vermont, 3 July 1986.
3. U.S. Geological Survey, 7.5' topographic map, scale 1:24000, Concord, Vermont, 1967.
4. U.S. Geological Survey, 7.5' topographic map, scale 1:24000, Miles Pond, Vermont, 1967.
5. U.S. Army Corps of Engineers, Field surveys, May and June, 1990.
6. U.S. Army Corps of Engineers, Flood Plain Information, Town of St. Johnsbury, December, 1972.
7. U.S. Army Corps of Engineers, water surface profiles computer program HEC-2.
8. U.S. Army Corps of Engineers, water surface profiles computer runs of 31 December 1990 (multiple run) and 2 January 1991 (floodway run).
9. Vermont's Property Valuation and Review Division, Agency of Administration, Vermont Base Map (aerial photos), scale 1:5000, sheet nos. 196216, 196212, 200212, 200216, and 200220, dated 1983.
10. U.S. Army Corps of Engineers, Historical Ice Jam Flooding in Maine, New Hampshire and Vermont, October 1980.

EXHIBIT 1 - REFERENCE MARKS ALONG THE MOOSE RIVER
IN CONCORD, VERMONT

- RM-1 A standard USGS disk stamped Elev. 817.170 ft., S 3 1922 set in the top of the east end of the south headwall of a small concrete culvert under the Maine Central Railroad tracks, 600 feet west of a road crossing. Elev. 817.70.
- RM-2 A standard USGS disk stamped Elev. 814.126 ft. T 3 1922 set in the top of the southwest wingwall of a concrete box culvert under the railroad tracks and 300 feet east of a road crossing. Elev. 814.13.
- RM-3 Top of an iron post (a section of railroad rail driven into ground), approximately 40 feet east of a railroad marker post. Elev. 810.60.
- RM-4 Top of a 3/4 inch steel post (reinforcing bar) which appears to be a property line pin on north side of track in a spruce thicket. Elev. 807.51.
- RM-5 Top of an iron fence post on the north side of the railroad tracks painted orange. Elev. 810.01.
- RM-6 Top of an iron fence post on the north side of the railroad tracks painted orange. Elev. 816.04.
- RM-7 A chisel square on top of the north headwall of a 3-foot culvert under the railroad tracks. Elev. 821.70.
- RM-8 A chisel square on top of a boulder flush with the ground approximately 15 feet from the edge of the north rail. Elev. 834.24.
- RM-9 A nail set in a 6-inch cherry tree on the south side of the railroad tracks. Elev. 837.05.
- RM-10 A standard USGS tablet stamped Elev. 859.198, U 3 1922 set in top of the west end of the granite capstone at the north end of a culvert under the railroad tracks. Elev. 859.20.
- RM-11 A nail in a 4-inch elm tree located near a railroad sign post marked (w) - Elm is approximately 20-feet northerly of north rail. Elev. 874.46.
- RM-12 A chisel square set on top of the upstream southerly end of the concrete railing of a town road bridge over the Moose River. Elev. 880.93.

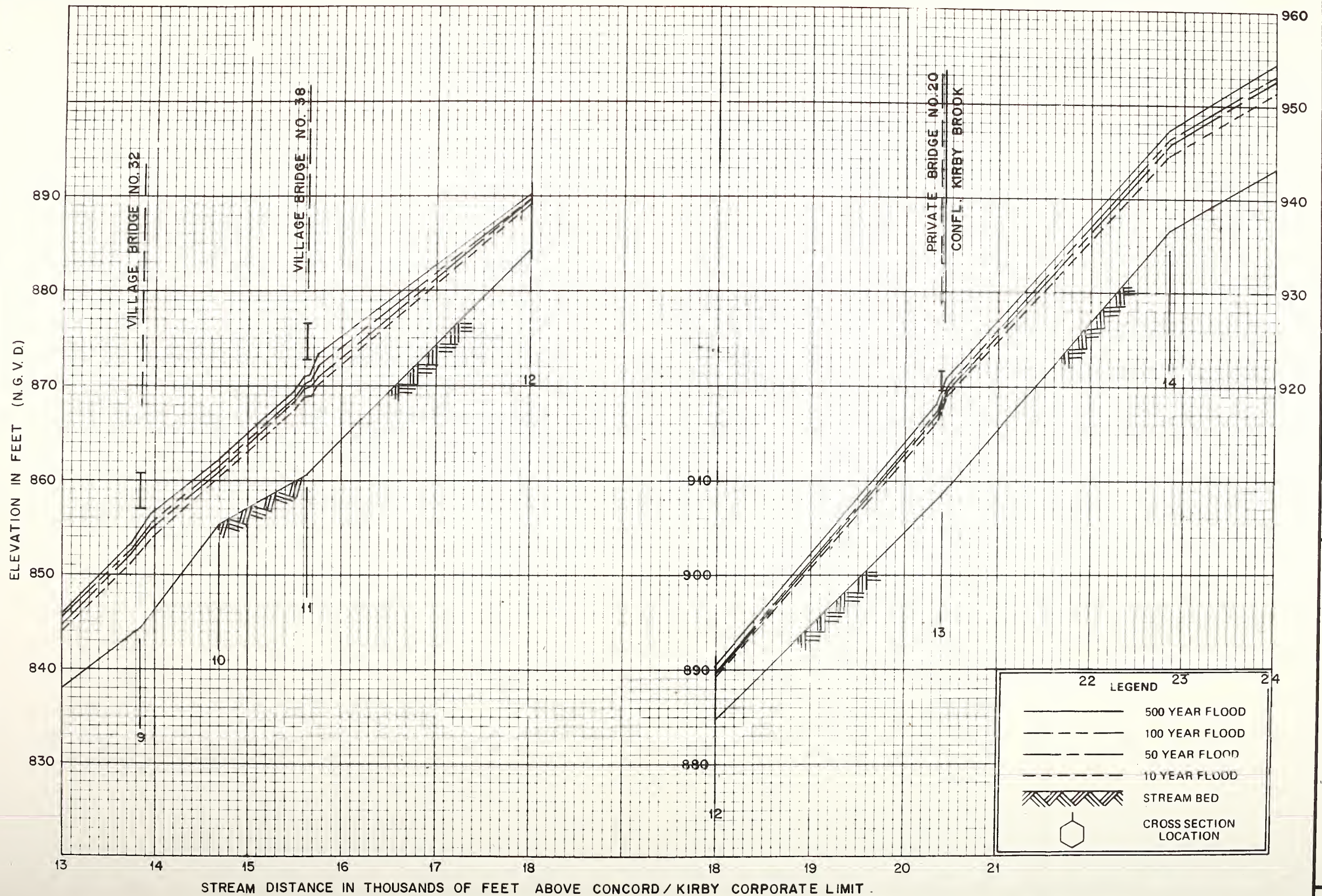
- RM-13 A nail in a power pole stamped 442/2 located at the intersection of a town road crossing the railroad tracks. Elev. 892.46.
- RM-14 A chisel square set on a boulder on the southerly side of the river and 25 feet northerly of north rail on a bank. Elev. 898.91.
- RM-15 A chisel square on top of the downstream northerly abutment of a bridge over the Moose River which goes to a private home. Elev. 921.69.
- RM-16 A Water Resources Gaging Station Tablet stamped "77 HBC 1965 922" set in a concrete block. Elev. 921.50.
- RM-17 A nail in a power pole stamped 44/45/1/50 NET&T located on the northerly side of Route 2 where the Moose River comes against the highway. Elev. 952.08.
- RM-18 A chisel square on top of a granite headwall for an 18-inch culvert under Route 2 by wooden marker post on northerly side of highway near a mobile home. Elev. 993.84.
- RM-19 At southerly end of Route 2 bridge over Moose River - in top of concrete wall of bridge - A Vermont State Highway Department standard disk stamped "76" HBC 1965 USGS" - Elev. 986.81.
- RM-20 On the southerly side of Route 2 - a nail in a power pole stamped NET&T 177 A/205. Elev. 978.22.
- RM-21 On the northerly side of Route 2 by a field drive - a nail in a power pole stamped 11 NET&T 11/213. Elev. 1013.00.
- RM-22 A nail in a 6-inch black cherry tree located on the river bank at edge of field. Elev. 977.09.
- RM-23 A nail in a 24-inch stump near 12-inch pine tree beside field drive. Elev. 987.61.
- RM-24 A nail in a 24-inch pine tree near green house. Elev. 987.10.
- RM-25 A nail in a 12-inch poplar where river touches Victory Road. Elev. 988.15.
- RM-26 By farm house on Victory Road - a nail in a power pole stamped 115 T/4435/1/1-6/1. Elev. 994.89.
- RM-27 A nail in a 10-inch white birch at entrance to gravel pit. Elev. 997.66.
- RM-28 On the top of curb on the downstream northerly end of bridge - a Vermont Highway Department tablet. Elev. 1013.26.



FLOOD PROFILES

MOOSE RIVER

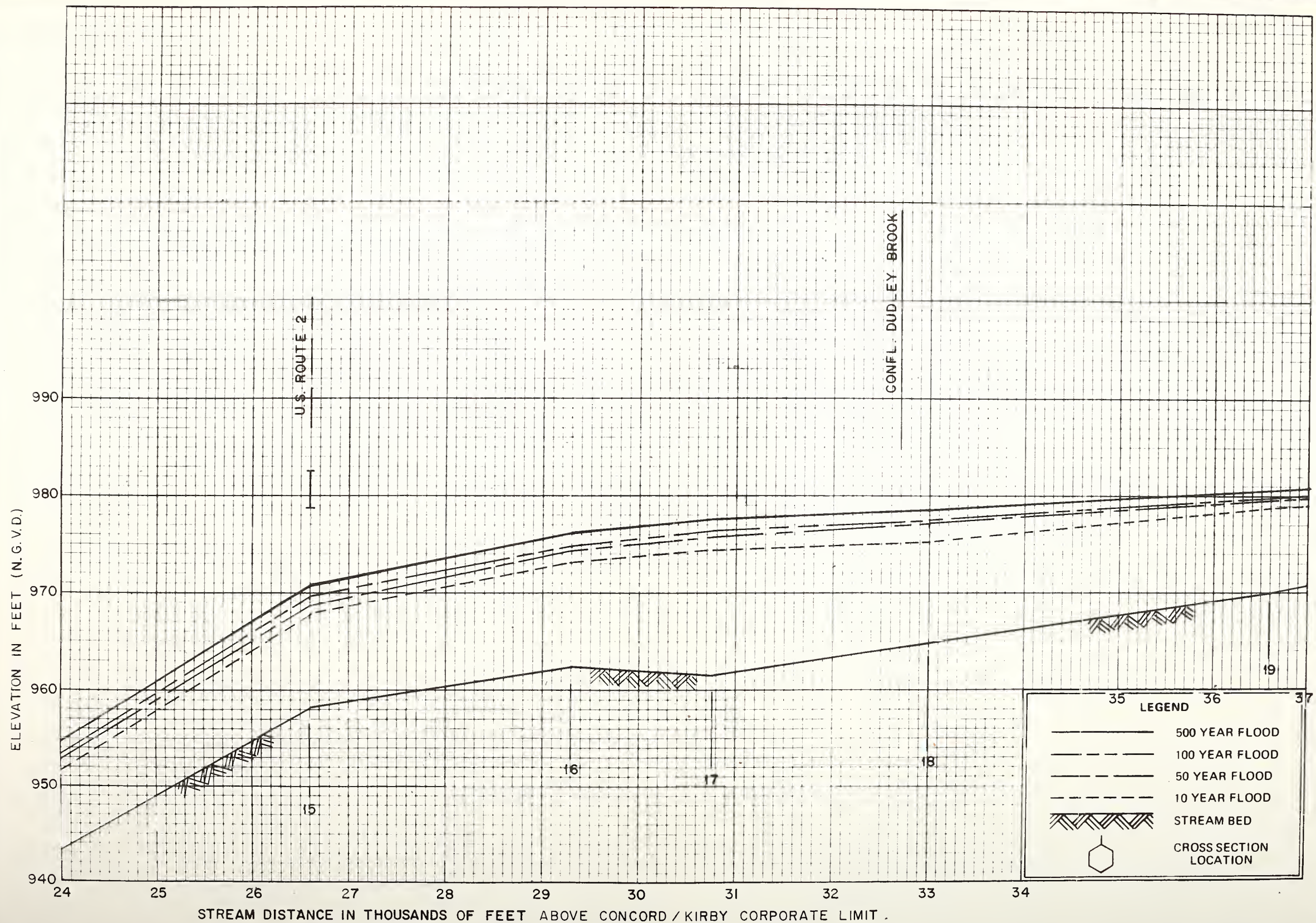
U.S. Army Corps of Engineers
CONCORD, VERMONT



FLOOD PROFILES

MOOSE RIVER

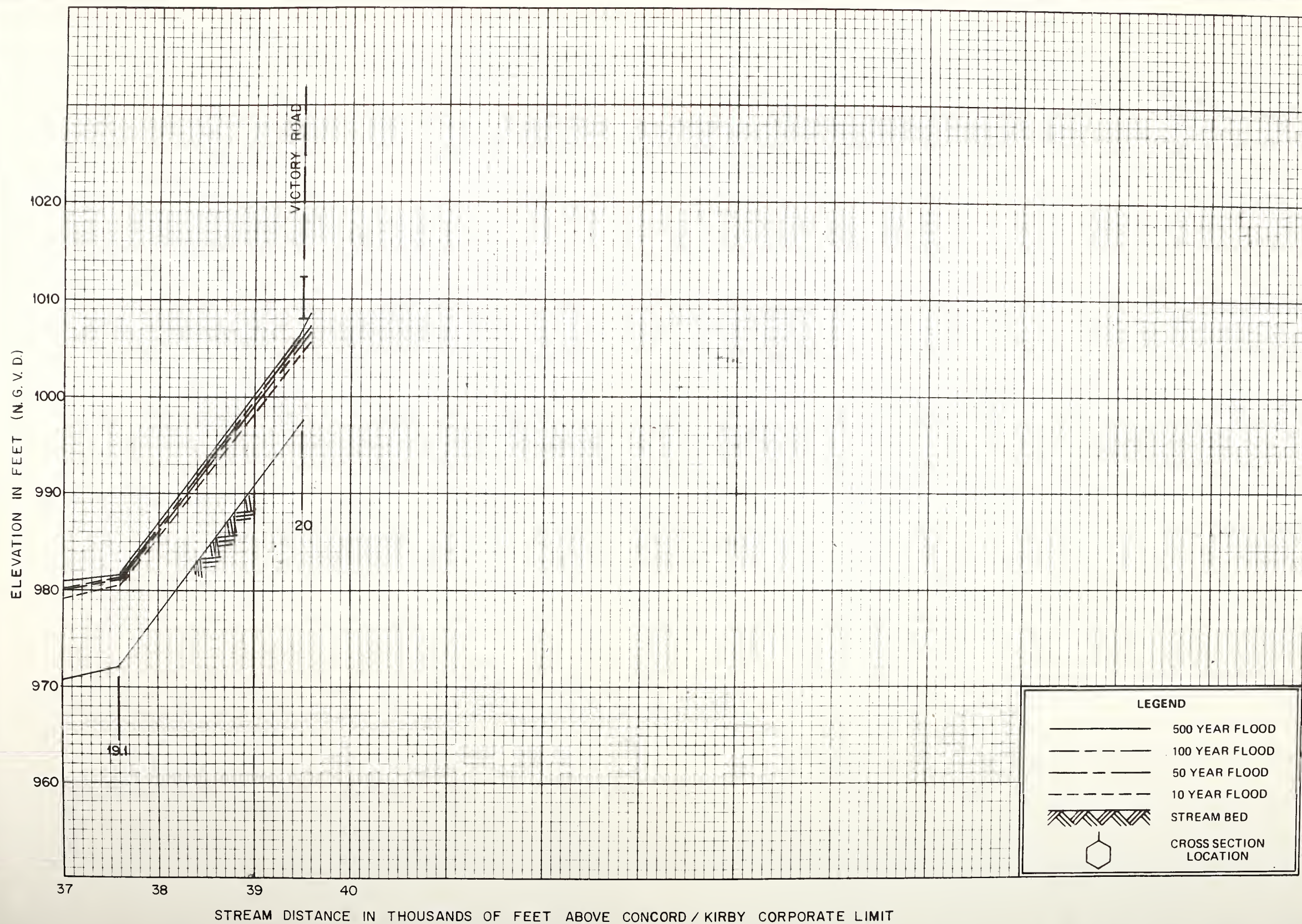
U. S. Army Corps of Engineers
CONCORD, VERMONT



FLOOD PROFILES

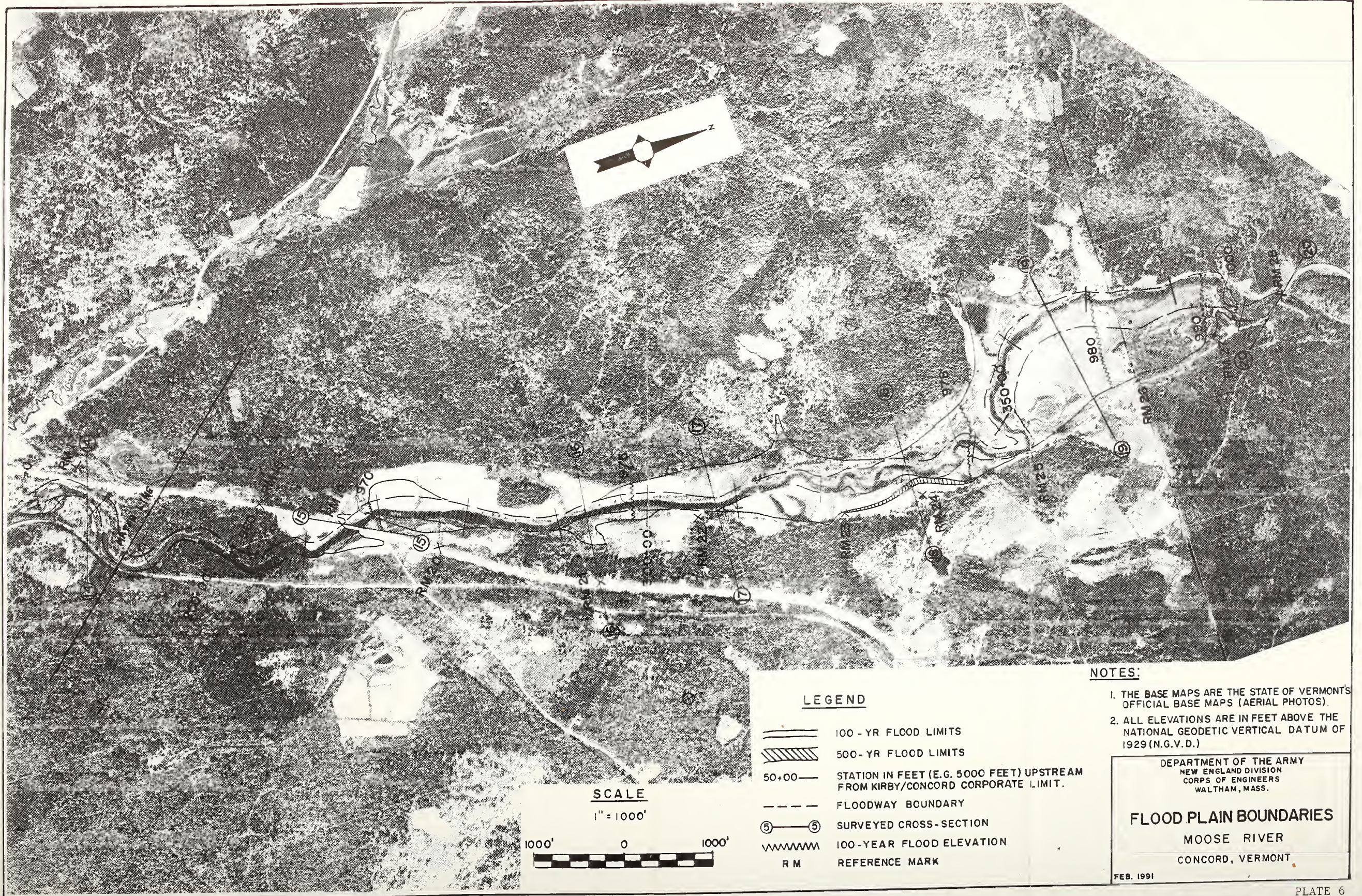
MOOSE RIVER

U. S. Army Corps of Engineers
CONCORD, VERMONT



LEGEND

- 500 YEAR FLOOD
- 100 YEAR FLOOD
- 50 YEAR FLOOD
- 10 YEAR FLOOD
- STREAM BED
- CROSS SECTION LOCATION




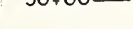
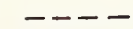

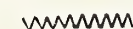


SCALE

1" = 1000'



LEGEND

-  100 - YR FLOOD LIMITS
-  500 - YR FLOOD LIMITS
-  STATION IN FEET (E.G. 5000 FEET) UPSTREAM FROM KIRBY/CONCORD CORPORATE LIMIT.
-  FLOODWAY BOUNDARY
-  SURVEYED CROSS-SECTION
-  100-YEAR FLOOD ELEVATION
-  RM REFERENCE MARK

NOTES:

1. THE BASE MAPS ARE THE STATE OF VERMONT'S OFFICIAL BASE MAPS (AERIAL PHOTOS).
2. ALL ELEVATIONS ARE IN FEET ABOVE THE NATIONAL GEODETIC VERTICAL DATUM OF 1929 (N.G.V.D.).

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

FLOOD PLAIN BOUNDARIES
MOOSE RIVER
CONCORD, VERMONT

FEB. 1991

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